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DC Motor Speed Control Using LabVIEW Program

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Introduction

Control systems are an integral part of modern society involves with different applications in the fields of engineering: electrical, mechanical, aerospace, biomedical, and chemical. These systems are concerned with the synthesis of the closed loop arrangement that depend on specific forms of output response for a given input excitation.

Key words: DC Motor, speed control, Labview. PID closed loop and open loop.

SYSTEM SIMULATION

In this section the controlled system is simulated on LabVIEW, the plant (motor) is represented as a function of time depending on the response of the system; therefore, it is important to determine the time constant of the output of the real system to build up simulation design.

The time constant of the output signal as captured previously in the open loop LabVIEW control is about 0.33 seconds with a final amplitude value of 0.88 volts, so the plant transfer function will be as following:

For accurate representation of the system, a simple control loop is designed to represent the delay between the input and the output signals from the step response, this value is then to be applied to the simulation loop as a time delay in the control signal and the feedback signal, this loop is shown in appendix. The measured delay time resulted is about 0.07 second.

OPEN LOOP SIMULATION DESIGN

Figure 1 shows a LabVIEW simulation design for the DC motor rig speed control, the simulated design is an open loop control.

The main components of the simulation loop are as follows:

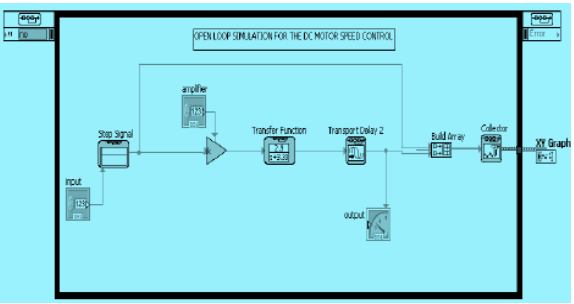


Figure 1: LabVIEW simulation design (open loop) for the DC motor rig speed control

Table 1: The tabulated results for the open loop LabVIEW simulation:

Input voltage (V)	Output voltage (V)	Steady state error (%)
1	0.88	12
2	1.76	12
3	2.64	12
4	3.52	12
5	4.4	12

According to table 1, the steady state error is 12% through all input values, however, 88% of the expected speed for each input is achieved, and this actually an acceptable error.

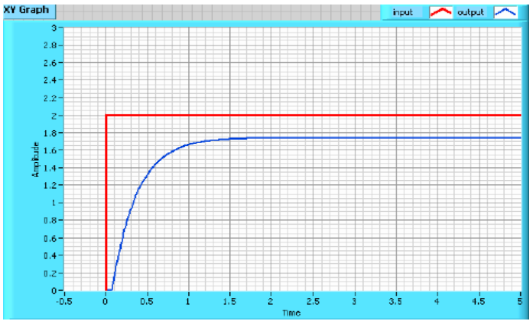


Figure 2: LabView plotted step response graph (open loop simulation) for the DC motor rig

From the plotted LabVIEW graph in figure 2, the steady state error is 12%, the settling time is about 1.5 seconds which is relatively a slow response, and the time constant is approximately 0.31 seconds.

PID CLOSED LOOP SIMULATION DESIGN

As show in the simulated design in figure 3, a feedback connection between the output and the input is made to obtain a closed loop control system, additionally, a similar PID controller to the one used in the LabVIEW control design is placed in the loop.
Another time delay unit is added, to the design within the feedback connection in order to represent the delay in the feedback signal in real system; the value of the delay time is the same as the output delay time.

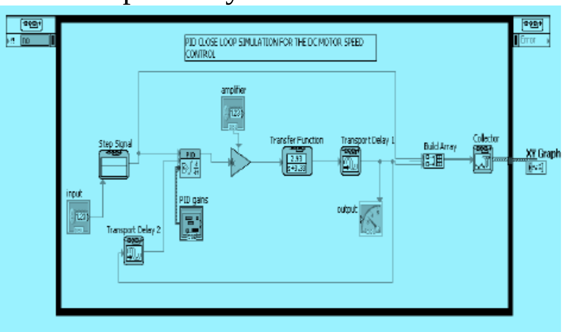


Figure 3: LabVIEW simulation design (PID closed loop) for the DC motor rig

Case 1 – Testing the loop with various amplifier gains

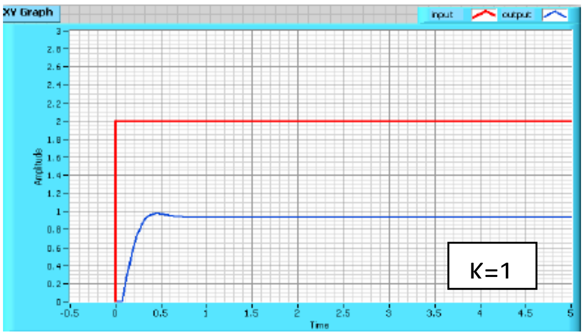
At first, the simulated design is tested in normal for various amplifier gains (1, 2, 3) and the parameters of the PID controller will not be changed (P = 1, I = 0, D = 0).

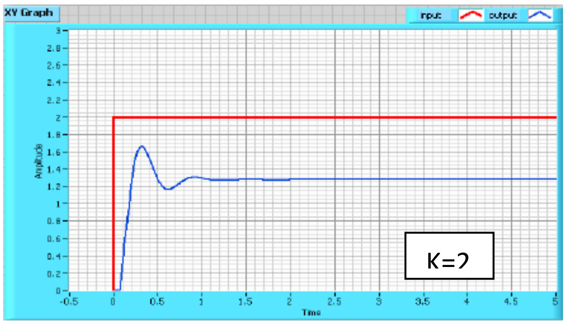
Table 2: The tabulated results for the PID closed loop LabVIEW simulation in various amplifier gains

Input voltage (V)	Output voltage (V)			Steady state error (%)		
	K=1	K=2	K=3	K=1	K=2	K=3
1	0.44	0.65	0.73	56	35	27
2	0.88	1.28	1.45	56	36	27.5
3	1.32	1.8	2.18	56	35	27.5
4	1.8	2.63	2.9	55	34	27.5
5	2.2	3.25	3.54	56	35	27

From the tabulated results in table 2, the output voltage of the motor increases as the amplifier gain increases. Thus at the amplifier gain of 1 the steady state error was about 56% that the output is only equal to 44% of the input. When the gain increased to the value of 2 the steady state error decreased to about 35% and so the speed is said to be raised up, similar improvement has been obtained by increasing the gain to 3, however, the output voltage increased to about 73% of the input reducing the error to about 27%.

The output response:





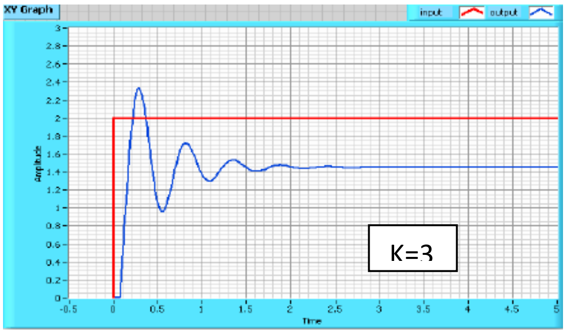


Figure 4: LabVIEW plotted step response graphs (PID close loop simulation) in various amplifier gains for DC motor rig

According to the plotted graphs in figure 4, the output response has improved by increasing the amplifier gain, in graph (a) when the gain is 1, the final output value is approximately equal to 44% of the input voltage, and the time constant is 0.12 seconds.
When the gain increased to 2 in graph (b), the output value has grown up to about 65% of the input value, and the time constant decreased to a value of 0.08 seconds, at this gain the system start to damp by an overshoot of about 30%. For the gain of 3 shown in graph (c), the output value increased to nearly 74% of the input value with roughly 0.04 seconds time constant, but the system tend to oscillate badly.

Implementing the tuned PID controller

In this case, similar PID parameters that have been tuned previously in LabVIEW control designs section are applied to the PID controller in the simulation design, so that the results can be comparable.

Table 3: The tabulated results for the tuned PID close loop LabVIEW simulation:

Input voltage (V)	Output voltage (V)	Error (%)
1	0.95	5
2	1.9	5
3	2.85	0
4	3.82	4
5	4.75	5

From the tabulated results in table 3, it can be seen that the steady state error is generally small (5%); however, the input values are close to the output values, so in this case the system performance has improved in terms of the output value.

The output response:

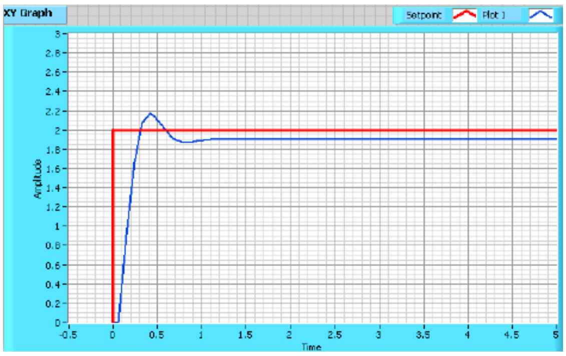


Figure 5: LabVIEW plotted step response graphs (tuned PID closed loop simulation) for DC motor rig

Regarding to the step response in figure 5, the output voltage is equal to 95% of the input voltage (5% steady state error) with an overshoot of approximately 8.5% and a settling time of 0.6 seconds, the time constant is about 0.13 seconds. Actually, this response can be considered as a smooth control.

DISCUSSION AND EVALUATION

To investigate the efficiency of the control design it is need to compare the designed loops; open loop, close loop and PID close loop, so the improvement in the system behavior can be noticed.

Figure 36 indicates the output result of the system for each control loop when , in open loop control the output is equal to the input value so that the motor is said to be run at 100% of its normal speed, in the other hand, the PID close loop output value is 95% of the input voltage. By looking at the behaviour of the output step response at each control system, the difference between the two control conditions is notable.

In the open loop the time constant is about 0.33 seconds and the system has no oscillations with a settling time of about 1.5 seconds, by implementing the designed PID controller to the close loop system the time constant has improved to 0.15 seconds with an overshoot of approximately 8% and settling time of nearly 0.5 seconds.
Finally, the fine smooth control is said to be achieved by obtaining the PID close loop control with the tuned PID controller parameters, furthermore, the output response of the system has become very closer to the ideal response.

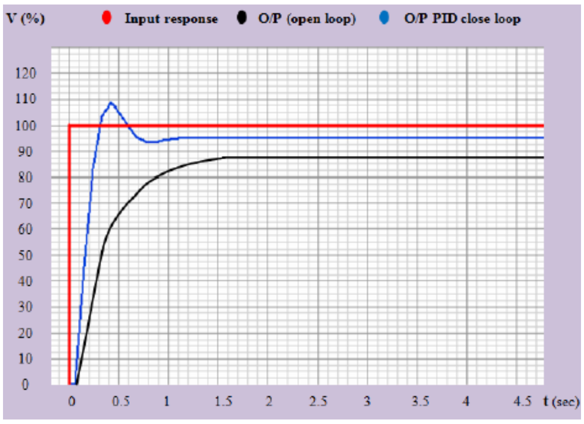


Figure 6: The step response of all LabVIEW simulation designs for the DC motor rig

COMPARING THE LABVIEW SIMULATION DESIGN RESULTS WITH THE LABVIEW CONTROL DESIGN RESULTS

By comparing the output values resulted in LabVIEW control designs with those resulted in the simulation design, it is evident that the difference between the values in both designs is very small in all cases.

For the output response, in open loop control the curves look close to each other in transient response and steady state error for both; LabVIEW and simulation designs. In case of implementing the designed PID controller. The step response graphs, in figure 7, shows the behavior of the output response in both LabView control and the simulation design, as clear from the graphs, there is no an effective difference between the output step response in case of LabView control and the simulation design ignoring the steady state error of 5% in the simulation design, while it is approximately zero in the control design.

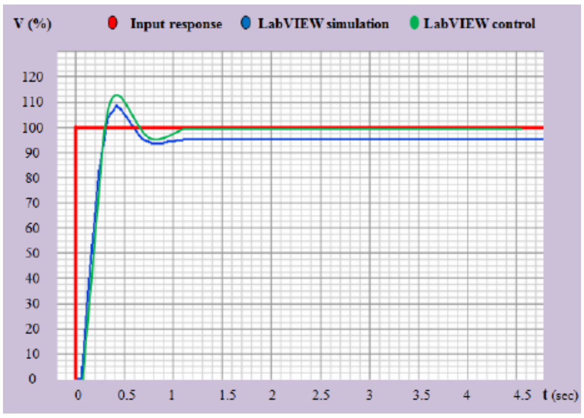


Figure 7: The step response of the PID closed loop in both; LabVIEW control and simulation designs

CONCLUTIONS

The main target of this project was to control the speed of a DC motor using LabVIEW program.

The results of LabVIEW control of the small DC motor rig have proved that a speed of a DC motor can be controlled by injecting a small signal voltage to change the DC voltage supply of the motor proportionally. Thus as the control signal increases the speed of the motor increase, in addition, the direction of the rotation can be reversed by supplying negative control signal.

The performance of the controlled system can be improved in terms of low output error and fast step response; however, the closed loop design is more efficient than the open loop design in steady state error reducing, especially when the load on the motor changed, because the closed loop can compensate for the error through the feedback connection.

Although the closed loop design has the feature of error correction, the control is still not smooth and confidant due to the high oscillations and maybe slow transient response. Interestingly, by adding the PID controller to the closed loop design, it was possible to improve the transient response and the steady state error due to the advantage of the adjustability of the PID parameters. However, the PID parameters could be tuned manually to result in a fast output response with no oscillation and zero steady state error, which has improved the performance and stability of DC motor rig speed control system.

The DC motor rig speed control system has been simulated using LabVIEW simulation program.

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